Design and Fabrication of Automated Powder Coating System

T. A. Selvan, A. Viswanathan, S. Madhankumar and S. Sneha

Abstract: ***In metal coating, powder coating is one of the important operations. Powder coating is a kind of solid coating without any solvent. This paper presents the design and fabrication of automatic powder coating system. The main purpose of this study is to upgrade the powder coating process with fully automated 3 axis moving machine and to reduce the usage of volatile organic compounds thus reducing the environmental impacts of the process. Metal detector is used to detect the presence of the object to be coated in the system. The motor, Spray gun, wheels and pneumatic valve are used in this system. A 3D model of the system is done using Solidworks to visualize the final outcome of the project. The main advantage of this system is that it decreases the manual labour and production time thus increasing production rate.***

Index Terms: ***Powder coating, Three axis machine and Spray gun.***

I. INTRODUCTION

The history of powder coating technology started around late 1940s when thermoplastic powder applied as coatings to metal and other substrates by flame spraying. Manual powder coating process is still in use in few companies [1], [2]. Powder is applied directly to the surface to be coated [3], [4]. It offers superior appearance, mechanical resistance properties, corrosion resistance properties, solvent resistance, fade and wear resistance, ready to use and require no mixing, solvents or catalysts [5]. This project is to automate this powder coating system in the industry. This reduces the time of production and usage of manual labour. It also reduces the amount of powder coating material used and scattered in air. This in turn reduces environmental pollution.

II. PROPOSED METHODOLOGY

The major components used here are

1. Base
2. DC Motors
3. Screw driver
4. Supporting shafts
5. Spray Gun
6. Pneumatic Valve
7. Pneumatic compressor
8. Raspberry pi3

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Dr. T. A. Selvan, Department of Mechatronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India – 641008.

Dr. A. Viswanathan, SNS College of Technology, Coimbatore, Tamil Nadu, India – 641035.

S. Madhankumar, Department of Mechatronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India – 641008.

S. Sneha, Department of Mechatronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India – 641008.

Base - The base is the outward shell that holds all the weight and moments of the components in place. It has the screw drivers and connecting shafts connected to it by bearings and flanges. It is also where the ac motors, controller and batteries for electrical connections are kept [6]. It is made up of rectangular hollow tubes welded to each other in the ends. Figure 1 shows the Computer Aided Model of base of automated power coating system.

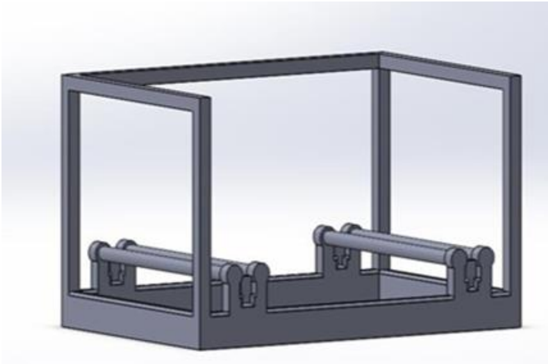

Figure 1. Base of Automated power coating system.

DC motors - DC motors are chosen for this project because they are easy to control and are precise [7]. It has DC drive attached to it which gets its input signals from the RASPBERRY PI 3 processor and in turn controls the motor and gives feedback signals to the processor.

Screw mechanism shafts - Here the rotational motion of the motor is converted to the linear movement by a screw mechanism. The motor is coupled to a shaft containing screw threads. By enclosing the screw with a nut, linear mechanism is obtained. Figure 2 shows the three-dimensional model of screw and thread.

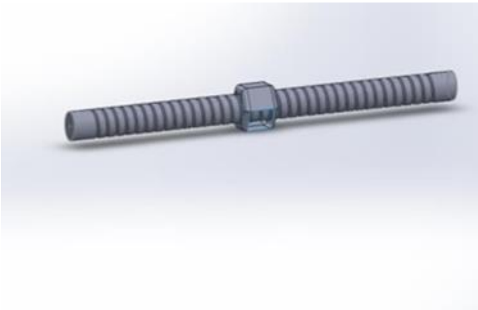

Figure 2. Screw and thread - 3D model

Supporting shafts - The supporting shaft shares the load of the screw mechanism and reduces the bending of the beam. This increases the factor

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of safety and life of the mechanism. Figure 3 shows the three-dimensional modeling for shaft with supports.

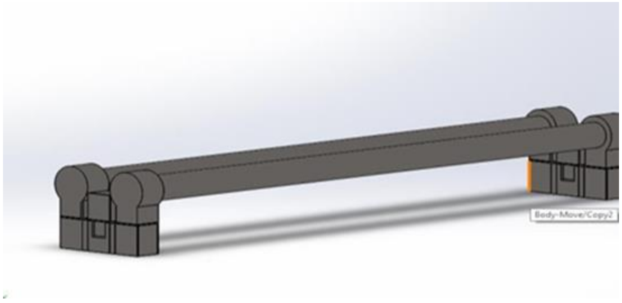

Figure 3. Shaft with supports

Spray Gun - The spray gun uses pneumatic power to spray the coating powder mixture to the workpiece. It is portable and is made of plastic thus reducing the weight of the total mechanism. Figure 4 shows the spray gun design.

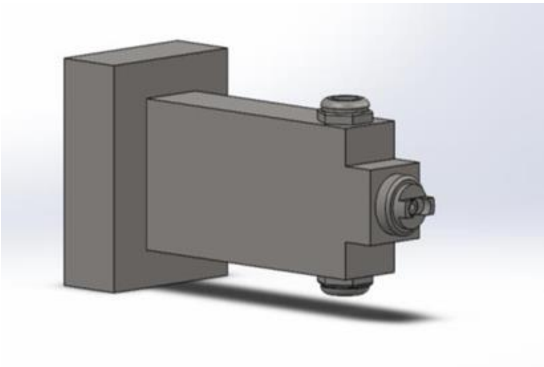

Figure 4. Spray gun design

Pneumatic Valve - The pneumatic direction control valve uses a cylinder and spool to control the direction of the flow of air. It can be operated by solenoids and springs.

Pneumatic compressor - These are rotating instruments that suck the outside air, increases pressure and then discharges it to the valve. The high pressure is used for spraying of powder through the spray gun nozzle [8]. The nozzle converts the pressure energy into kinetic energy thus increasing the velocity of the particles of powder to be coated on the workpiece.

RASPBERRY PI 3 - The RASPBERRY PI 3 is a small sized computer that could control and process various complex process. It features 1.2 GHz quad- core 64-bit Arm Cortex A53 processor, Chip antenna, 4 USB ports, an Ethernet Port, a GPIO, HDMI, 3.5mm Audio Output, WIFI chip, 1GB LPDDR2 for RAM Memory, and a MicroSD slot.

III. RESULTS AND DISCUSSION

A. *Working*

The proposed system uses metal detecting sensors to identify the metal components in their place accurately. This information is sent to the controller, RASPBERRY PI 3 which processes this information. After the position and dimensions of the component is determined, the processor finds the shortest passage to coat the whole body. This is then calculated into various positions and signals for the 3 motors that control the major shafts. The motors get this input and act accordingly. These 3 motors are used to control the movement of the Spray gun in three axes. The spray gun is connected to the vertical shaft. This in turn is controlled by a pneumatic mechanism. This mechanism consists of direction control valve and air pump. This control valve also gets its input data from the RASPBERY PI3 controller. Thus, the powder material is sprayed on the workpiece.

B. *Calculations*

X Axis Linear Bearing Calculation

On x axis (2 rail,2 bearing)

$F_{comb} = |F_y| + |F_z| + C_o\{(|M_y|/M_{lo}) + (|M_z|/M_{lo})\}$

$= 9.81+(2240*0.5886)$

$= 1328.274N$

X axis linear bearing P = 328.274

N = 150 L_H = 20000.18hr

$L_H = (C/P)^3 * (10^6/(60*N))$

$C = \{(20000 * (328.274)^3 * 60 *150)/ 10^6\}^{1/3}$

$= 44.31$

Y axis bearing Radial dynamic load

$F_{dr} = XF_r + YF_a$ X=1, Y=0

Here F_r = 6.54 N

$F_a = 0$

F_{dr} = 6.54N

Axial dynamic load $F_{da} = F_a + 1.2F_r$

=7.848N

Equivalent dynamic load L_h = 20000

N = 150 rpm

$L_H = (C/P)^3 * (10^6/(60*N))$

$C = \{(20000 * (328.274)^3 * 60 *150)/10^6\}^{1/3}$

$= 44.31$

Y axis linear bearing calculation:

Linear bearing

On Y axis (1 rail, 1 bearing)

$F_{comb} = |F_y| + |F_z| + C_o\{(|M_x|/M_{LO}) + (|M_y|/M_{LO}) + (|M_z|/M_{LO})\}$

$M_x = 19.62 * 0.03$

$= 0.5886$

$C_o = 2240$

$F_{comb} = 19.62+(2240*0.5886)$

$= 1338.08$ N

Y axis bearing Take

L_h=20000 (8 hrs shift)

$L_H = (C/P)^3 * (10^6/(60*N))$

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$20000 = (C/1338.08)^3 * \{(10^6)/ (60*150)\}$

$C = 7555.08$

Z axis bearing

Z Axis up and down movement

Volume $= 387887.32*10^{-9}$ m^3

Mass = volume * density

$= 387887.32 * 10^{-9} * 7700$

$= 2.89$ kg

$= 3$ kg Take

Sprayer + Pneumatic mechanism = 1kg

Total = 4 kg; Weight = 4*9.81 = 39.24 N

$L_h = 20000$

$L_H = (C/P)^3 * (10^6/ (60*N))$

$C = \{(20000*(39.24)^3 * 60 * 150)/ 10^6\}^{1/3}$

$= 221.551$

$= 222$ Take

Z axis screw

Slenderness ratio

$I = 3.14/ 64(0.03)^4$

$= 3.974*10^{-8}$

$A = 3.14/4(0.03)^2$

$= 9.06*10^{-4}$

$K = 0.564*10^{-2}$

$= 5.624$ mm

Length = 50 cm

l/k = (50*10-2)/ (0.564*10-2)

$= 88.89$

$S_{yt}/2 = n^2E/(l/k)^2$

$E_{steel} = 215*10^9 N/m^2$

$(S_{yt})_{steel} = 237.8*10^6 N/m$ N = 1(hinged on both sides)

$237.8*10^6 = (1*(3.14)^2*215*10^9)/ (l/k)^2$

$(l/k) = 20.73$

Slenderness ratio is less Euler equation is used

$P_{cr} = (n^2EA)/(l/k)^2$

$P_{cr} = 243kN$

Stress on Y axis plate

$areaP/_y = 13.08/ 410*10^6$

$= 0.0319*10^{-6}$ Base.

C. *Assembly Diagram*

Figure 5 and Figure 6 shows the assembly diagram with part description and isometric diagram for automated powder coating system using Solidworks software.

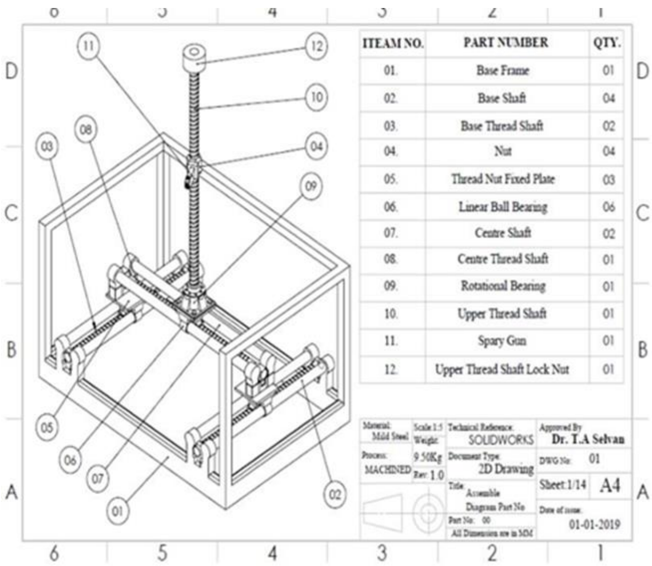

Figure 5. assembly diagram with part description

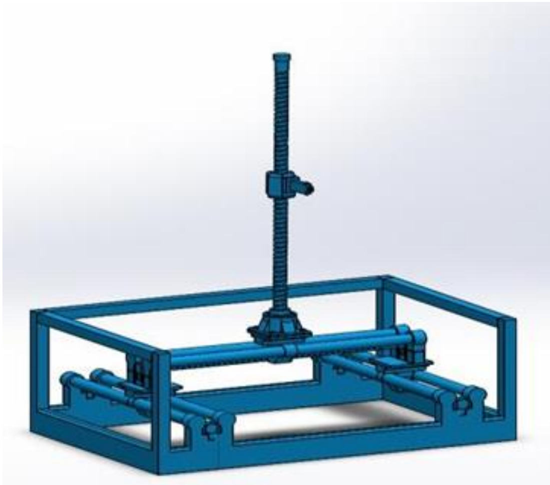

Figure 6. Isometric diagram

IV. CONCLUSION

This automatic powder coating system reduces the cost and time spent on the process. It reduces the need for manual labour and also could be manufactured at a much lower cost than the original system.

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